RESULTS OF A MICROBIAL WEATHERING STUDY OF COMPOSTED EXPLOSIVES-CONTAMINATED SOIL OBTAINED FROM THE UMATILLA ARMY DEPOT ACTIVITY

Hermiston, Oregon

Second Phase Testing

(September 1998 to September 1999)

Prepared for

U.S. Army Environmental Center (USAEC)

Aberdeen Proving Ground, Maryland 21010-5401

Prepared by

Tennessee Valley Authority

P.O. Box 1010

Muscle Shoals, Alabama 35662-1010

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This report describes the results of the third and final year (September 1998 through September 1999) of a Microbial Weathering Study conducted to determine if composted explosives-contaminated soil would leach explosives or explosive by-products. The study was conducted using compost produced during the remediation of an explosives-contaminated site at the U.S. Army's Umatilla Army Depot Activity at Hermiston, Oregon. This compost was shipped to the Tennessee Valley Authority's Environmental Research Facility in Muscle Shoals, Alabama, where the study was conducted. The results of the third year of the study confirmed the results of the first two years of the study and these were that no TNT or TNT breakdown products were leached from the compost but as much as 31.5 and 26.4 ppb of HMX and RDX, respectively, were leached. These results suggest that HMX and RDX were not fully mineralized in the composting process. However, the concentrations leached were well below the state of Oregon's action limit of 30 ppm. Analysis of compost revealed that TNB was the only explosive breakdown product remaining in the compost after being weathered three years. Concentrations of TNB in the compost were less than 0.5 ppm. The results of the first two years (September 1996 - September 1998) of the Microbial Weathering Study are provided in USAEC Report No. SFIM-AEC-ET-CR-98042.

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Executive Summary

This report summarizes the third and final year (September 1998 through September 1999) of a study examining the microbial weathering of compost produced from the remediation of explosives-contaminated soil at the Umatilla Army Depot Activity (UMADA), Hermiston, Oregon. The first two years of the study are reported in detail in *Results of a Microbial Weathering Study of Composted Explosives-Contaminated Soil Obtained from UMADA.* [Ref 1] The microbial weathering study was part of a larger study aimed at determining if compost produced from remediating explosives-contaminated soils contained explosive residues or explosive transformation products that might be of concern. Specifically, the larger study was to determine if these chemicals could be:

- Taken up by plants which, in turn, might be consumed by livestock or people or be
- Leached from the compost when stockpiled or land applied.

A detailed description of the larger study and its results are provided in the final report, *Results of a Study Investigating the Plant Uptake of Explosive Residues from Compost of Explosives-Contaminated Soil.* [Ref 2] The Microbial Weathering Study began September 15, 1996 and ended September 15, 1999. This report deals with the third and final year of the study, September 15, 1998 through September 15 1999.

This project was executed under an agreement between the U.S. Army environmental Center (USAEC) and the Tennessee Valley Authority (TVA). The USAEC was the lead agency while TVA provided technical expertise in composting and explosives residue analysis. All of the test work was conducted at TVA's facilities in Muscle Shoals, Alabama.

The weathering of the compost was accomplished in large plastic containers placed above ground to facilitate the collection of leachate. Over the course of the study, leachate

resulting from precipitation events was periodically collected and chemically analyzed to determine if explosive residuals were leaching from the compost. Three containers were filled with immature compost from the UMADA composting activity and three containers were filled with uncontaminated soil from UMADA amended with compost mixed in the top six inches. At the end of the second year of the study, September 15, 1998, the three containers filled with soil and compost were abandoned and a single container filled with uncontaminated soil from UMADA was included in the final year of the study. This change was made because continued sampling of leachate from the soil amended with compost was deemed unnecessary since leachate samples contained no detectable levels of explosives or explosive by-products after March 1997, six months after the study began. The uncontaminated soil was included in the third year of the study to determine if it contained explosives or explosive by-products that could be leached. Data from early in the study (from September 1996 to March 1997) indicated that the uncontaminated soil was actually contaminated with HMX and RDX. During this time, leachate from the compost-amended soil containers contained higher levels of HMX and similar levels of RDX when compared to leachate from the containers filled with only compost.

Four procedural changes were made in the last year of the study.

1. Grab samples of leachate were taken instead of composite samples.
2. Rainfall and total leachate volumes were not measured.
3. Samples were split and one split was filtered through a 2-µm glass fiber filter before being analyzed.
4. Leachates were analyzed for mononitroso-RDX and trinitroso-RDX in addition to the ten compounds for which samples were analyzed in the first two years of the study (see Table 1).

The change in the composition of compost over time was determined by analyzing samples of compost taken from the weathering containers annually.

Compost analyses revealed that, after three years of weathering, there were low levels (<0.5 mg/Kg) of trinitrobenzene in some of the compost samples. No other explosives or explosive by-products were detected in the compost.

All but two of the leachate samples taken during the final year of the study had undetectable levels of explosives and explosive by-products. The two exceptions were the first two samples collected in the final year from the No. 1 Weathering Container (samples collected November 1998 and January 1999). The highest level of RDX was 5.0 μg/l found in the filtered sample collected in November 1998. No other analytes were detected. The comparison of the filtered and unfiltered leachate samples revealed that the RDX was in solution and not bound to soil or humus particles. There was practically no difference in the RDX levels in filtered and unfiltered samples.

Even though no explosives were found in the leachate from the uncontaminated UMADA soil it is believed that the soil was contaminated. To ascertain if the UMADA soil was actually free of explosives a separate test was conducted involving the extraction of contaminants using HPLC-grade water (distilled water filtered through a 2-μm filter). The results of this test revealed that the UMADA soil was not free of explosives but had small amounts of explosive mixed heterogeneously in the soil.

The results of the final year of the study confirmed the results of the first two years of the study and these were:

- The compost produced from remediating explosives-contaminated soil had very low levels of explosive when delivered to TVA. The primary contaminant in the UMADA soil, TNT, was not detected in the compost.
- Neither TNT nor its degradation products were detected in leachate samples.
- Small amounts of RDX and HMX were the only analytes detected in leachate samples.

- Levels of RDX and HMX in leachate dropped to levels that were barely detectable after a few months of weathering.

ABBREVIATIONS

2,6-DANT	-2,6-Diamino-4-nitrotoluene or 2,6-DA-4-NT
2,4-DANT	-2,4-Diamino-6-nitrotoluene or 2,4-DA-6-NT
2,6-DNT	-2,6-Dinitrotoluene
2,4-DNT	-2,4-Dianitrotoluene
2-ADNT	-2-Amino-4,6-dinitrotoluene
4-ADNT	-4-Amino-2,6-dinitrotoluene
DNT	-Dinitrotoluene
HPLC	-High Performance Liquid Chromatography
HMX	-Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
MDL	-Method Detection Limit
MONO-RDX	-Mononitroso-RDX
RDX	-Hexahydro-1,3,5-trinitro-1,3,5-triazine
TNB	-Trinitrobenzene
TNT	-2,4,6 Trinitrotoluene
TRI-RDX	-Trinitroso-RDX
TVA	-Tennessee Valley Authority
UMADA	-Umatilla Army Depot Activity
USAEC	-U.S. Army Environmental Center

Introduction

The data presented in this report was obtained from the third year of a three-year microbial weathering study. The microbial weathering study was conducted to determine if explosives or explosive by-products could be leached from explosives-contaminated soil that had been remediated by composting. This microbial weathering study was part of a larger study which determined if explosives or explosive by-products could be taken up by plants that would, in turn, be consumed by humans or livestock.

The project was originally funded for two years. During this two year period the plant uptake study was completed as was two years of the weathering study. Also, final reports of the two studies were completed, one of the plant uptake study (Reference 2) and one of the weathering study (Reference 1). When the decision was made to continue the weathering study for a third year, a decision was made to summarize the third year of the weathering study in a separate report and not write a comprehensive report involving three years of weathering data. This report, therefore, contains only the data obtained in the third year of the study and the changes in the experimental design that were implemented in the third year of the study. A complete description of the experimental design, sampling methods, analytical methods, and the data collected in the first two years of the study, can be found in Reference 1, *Results of a Microbial Weathering Study of Composted Explosives-Contaminated Soil Obtained from the Umatilla Army Depot Activity.*

Compost Description

The compost used in the study was obtained from an operation at the UMADA where explosives-contaminated soil had been remediated by composting. A complete description of the compost is included in Reference 1. Three of the weathering containers were filled with the immature compost. The term 'immature' means that the compost was taken from the UMADA remediation activity shortly after treatment, but before microbial activity had reached low levels. The three weathering containers filled with the compost were designated No. 1, 2, and 3. Containers 4, 5, and 6 were filled with uncontaminated soil from UMADA that was amended with the same immature compost mixed into the top six inches of soil.

In the second year of the study (September1997 through September 1998) the compost amended soil containers produced no leachate with detectable levels of explosives. Consequently, these containers were eliminated from the study in the third year and were replaced with a single container filled with UMADA soil. The UMADA soil was included in the third year of the study to determine if it contained explosives or explosive by-products that could be leached. The reasoning for this was that, early in the study, (September 1996 to March 1997) the compost-amended-soil containers (Containers 4, 5, and 6) produced leachate with higher levels of HMX than did the containers filled completely with compost. Only 4 pounds of dry compost per container were used to amend the soil while the compost containers each held 450 pounds of compost. The 4 pounds appears small in comparison, however, on a per-acre basis it was equivalent to 28,000 pounds and would supply around 150 pounds of nitrogen per acre.

The weathering container filled with UMADA soil had previously contained soil amended with compost and had been designated No. 4. This container was selected for UMADA soil because it had previously been fitted with a filtered drain to ensure that its outlet could not be clogged by soil particles. The following procedure was used in setting up the new weathering container.

The container was emptied and its contents were properly disposed of. The empty container was washed and scrubbed with soapy water and then rinsed with tap water. A final rinse was done using deionized water. The container which has a capacity of 265 liters (70 gal) was filled with 650 pounds of uncontaminated UMADA soil in 9 increments, each weighing around 72 pounds. An oven dry test of the soil revealed that it had a moisture content of 7.6 % on a dry weight basis. The soil was taken from a large nylon bag of soil that was left over from the initial setup of the study in September 1996. The bag of soil had been stored outside and was covered to prevent exposure to sunlight and precipitation.

Despite the strong evidence that the UMADA soil was contaminated, the leachate samples it produced had no detectable levels of explosives. To ascertain if the soil was actually free of explosives a more aggressive leaching procedure was used. Two 3-kg samples of soil taken from the stockpile of uncontaminated soil were tested in the following manner. Both samples were mixed in 800 ml of HPLC-grade water. After thoroughly mixing the soil and water, the mixtures were allowed to stand for two days and were remixed twice more over a four-day period. Supernatant from each batch underwent centrifugation, then filtration through a glass-fiber-filter train having a cartridge with 0.45 μm pore size followed by a cartridge with 0.2 μm pore size. Two 38-ml aliquots of filtrate from each batch were extracted using the same method used for leachate samples in the study. The extracts from one of the batches contained no analytes above the method detection limit (less than 0.133 μg/kg HMX, and less than 0.160 μg/kg RDX), the extracts from the second batch contained low levels of both HMX and RDX with the average level of 1.29 μg/kg for HMX and 2.10 μg/kg for RDX.

The results of this test revealed that the UMADA soil was not free of explosives but had small amounts of explosive mixed heterogeneously in the soil. The soil placed in the weathering containers in September 1996 invariably contained leachable levels of HMX and RDX.

Experimental Design

The complete discussion of the experimental design can be found in Reference 1. In this report only those procedures and methods that were changed for the third and final year of the study will be described. In the first two years of the study, six weathering containers were used, three filled with compost and three filled with compost-amended soil. In the final year, four containers were used, three filled with compost and one filled with UMADA soil.

In the first two years of the study, precipitation amounts were measured and recorded. The total volume of leachate that was collected from each container was also recorded. In the final year these data were not collected for two reasons, 1) considerable man hours of labor were required to collect these data and 2) these data had limited value in interpreting the pattern of contaminant loading of the leachate.

Leachate samples were collected and composited prior to analysis during the first two years of the study. In the third year, grab samples were collected for analysis. This procedure was also implemented to save labor and cost. To composite all of the leachate for analyses, the leachate collection system had to be checked almost daily and often on weekends. The use of grab samples reduced labor requirements to a few hours per the two-month sampling interval.

Leachate samples were analyzed for two addtional analytes during the third year of the study. The degradation products of RDX, mononitroso-RDX and trinitroso-RDX, were added to the ten compounds for which the leachate samples were analyzed in the first two years of the study. Table 1. lists the analytes for which the leachate samples were analyzed in the third year of the study. The sampling frequency and analytical method used are also listed in Table 1. Other details concerning analytical procedures can be found in Reference 1.

Table 1. Analysis of Leachate

Parameter Measured	Frequency	Method
TNT	Every two Months	Modified 8330
TNB	Every two Months	Modified 8330
HMX	Every two Months	Modified 8330
RDX	Every two Months	Modified 8330
Mononitroso-RDX	Every two Months	Modified 8330
Trinitroso-RDX	Every two Months	Modified 8330
2,4 DNT	Every two Months	Modified 8330
2,6 DNT	Every two Months	Modified 8330
2A-DNT	Every two Months	Modified 8330
4A-DNT	Every two Months	Modified 8330
2,6 DANT	Every two Months	Modified 8330
2,4 DANT	Every two Months	Modified 8330

In the third year of the study each leachate sample was split and one split was filtered before being analyzed to determine if explosive residues were in solution or were attached to solids or bacteria in the leachate. The filtered samples were passed through a filter train which had two glass fiber filters, the first having 4.5-µm openings and the second having 2-µm openings. This was to yield a total of 48 leachate analyses, 4 bins times 6 rounds times 2 analyses per sample. Due to a severe drought which occurred near the end of the final year of the study, no leachate was produced during July, August, or September. Consequently, the final two leachate samples, July and September, could not be collected. With concurrence from the USAEC a fifth set of leachate samples was produced in August by sprinkling deionized water over the weathering containers. The following procedure was used to collect the fifth and final round of leachate samples.

1. The equivalent of 1 inch of rainfall (15 liters) of deionized water was sprinkled over each container.
2. After waiting one hour the leachate collection bottles were checked. If the leachate volume was equal to or greater than 250 ml then it was placed in an amber glass bottle, wrapped in aluminum foil, and transported to the laboratory.
3. If the first 15 liters of deionized water did not produce enough leachate, then another 15 liters of deionized water was sprinkled on top of the compost.
4. After waiting another hour, the leachate collection bottle was again checked for leachate. If the leachate volume was greater than or equal to 250 ml then the leachate was collected and transported to the laboratory.
5. The procedure of adding 15 liters of deionized water to the containers was repeated until enough leachate was produced to fill a 250-ml collection bottle.
6. The total amount of water added to the containers was recorded as was the amount of leachate produced prior to collecting the sample.

Table 2. lists the amount of water that was applied to the soil or compost in each container, the amount of leachate collected for sample analysis, and the total amount of leachate produced from the water addition. The total volume of leachate was measured and recorded the following day, at which time the flow of leachate had stopped.

Table 2. Water Applied for Leachate Production

Weathering Container	Container 1 (Compost)	Container 2 (Compost)	Container 3 (Compost)	Container 4 (Soil)
Water Added (L)	30.0	30.0	30.0	45.0
Initial Leachate Volume (L)	1.85	2.36	3.50	7.50
Total Leachate Volume (L)	2.35	2.79	3.60	11.4

Compost in the weathering containers was sampled and analyzed annually to measure the changes in composition due to weathering. At the end of the third year of the study the

compost was sampled by removing three cores from each container using a hollow-tube soil sampling device. The cores were taken in stages. That is, the top 15 cm of the compost was extracted first, then the middle 15 cm of the compost was extracted, then the bottom 15 cm was extracted. The corresponding layers from the cores taken from each container were combined so that the top, middle, and bottom layers of compost in each weathering container could be separately analyzed. The compost was analyzed for the same compounds as was the leachate (see Table 1.).

Study Results

The results of the analyses of leachate samples are shown in Tables 3 through 6. The dates when the samples were taken, the amount of leachate associated with the sampling event and the method detection limits (MDL) are listed for each sample. During the third year of the study only two samples contained detectable levels of explosive material, the November 1998 and January 1999 samples from the No. 1 weathering container. These two samples contained low levels of RDX, 4.08 μg/L, 5.0 μg/L, 3.25 μg/L, and 3.38 μg/L, respectively, for the unfiltered and filtered samples taken November 13, 1998 and January 8, 1999. The levels were similar for the filtered and unfiltered samples indicating that the RDX was in solution and not bound to soil, humus, or bacteria.

Table 3. Analysis of Leachate from Weathering Container No. 1

Analyte	Explosives Analyses and Method Detection Limit '(μg/L) Date									
(μg/L)	11/13/1998		01/08/1999		03/10/1999		05/07/1999		08/25/1999	
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
HMX	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
RDX	4.08 (0.647)	5.00 (0.568)	3.25 (0.553)	3.38 (0.647)	ND (0.584)	ND (0.537)	ND (0.576)	ND (0.553)	ND (0632)	ND (0.584)
TRI-RDX	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
MONO-RDX	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
TNT	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
TNB	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
2,6-DA-4-NT	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
2,4-DA-6-NT	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
2,6-DNT	ND (0.647)	ND (0.568)	ND (0.553)	ND (0.647)	ND (0.584)	ND (0.537)	ND (0.576)	ND (0.553)	ND (0632)	ND (0.584)
2,4-DNT	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
2-ADNT	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
4-ADNT	ND (0.539)	ND (0.474)	ND (0.461)	ND (0.539)	ND (0.487)	ND (0.447)	ND (0.480)	ND (0.461)	ND (0.526)	ND (0.487)
Volume (L)	2.92		9.09		18.7		22.9		17.3	

ND = Not Detected (Below Method Detection Limits)
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
TRI-RDX = Trinitroso-RDX
MONO-RDX = Mononitroso-RDX
TNT = 2,4,6-Trinitrotoluene
TNB = Trinitrobenzene
2,6-DA-4-NT = 2,6-Diamino-4-nitrotoluene
2,4-DA-6-NT = 2,4-Diamino-6-nitrotoluene
2,6-DNT = 2,6-Dinitrotoluene
2,4-DNT = 2,4-Dinitrotoluene
2-ADNT = 2-Amino-4,6-dinitrotoluene
4-ADNT = 4-Amino-2,6-dinitrotoluene

Table 4. Analysis of Leachate from Weathering Container No. 2

Analyte (μg/L)	Explosives Analyses and Method Detection Limit '(μg/L) Date									
	11/13/1998		01/08/1999		03/10/1999		05/07/1999		08/25/1999	
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
HMX	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
RDX	ND (0.632)	ND (0.600)	ND (0.632)	ND (0.632)	ND (0.553)	ND (0.600)	ND (0.584)	ND (0.553)	ND (0.568)	ND (0.568)
TRI-RDX	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
MONO-RDX	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
TNT	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
TNB	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
2,6-DA-4-NT	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
2,4-DA-6-NT	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
2,6-DNT	ND (0.632)	ND (0.600)	ND (0.632)	ND (0.632)	ND (0.553)	ND (0.600)	ND (0.584)	ND (0.553)	ND (0.568)	ND (0.568)
2,4-DNT	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
2-ADNT	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
4-ADNT	ND (0.526)	ND (0.500)	ND (0.526)	ND (0.526)	ND (0.461)	ND (0.500)	ND (0.487)	ND (0.461)	ND (0.474)	ND (0.474)
Volume (L)	3.54		5.02		18.6		16.1		2.36	

ND = Not Detected (Below detection limits)
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
TRI-RDX = Trinitroso-RDX
MONO-RDX = Mononitroso-RDX
TNT = 2,4,6-Trinitrotoluene
TNB = Trinitrobenzene
2,6-DA-4-NT = 2,6-Diamino-4-nitrotoluene
2,4-DA-6-NT = 2,4-Diamino-6-nitrotoluene
2,6-DNT = 2,6-Dinitrotoluene
2,4-DNT = 2,4-Dinitrotoluene
2-ADNT = 2-Amino-4,6-dinitrotoluene
4-ADNT = 4-Amino-2,6-dinitrotoluene

Table 5. Analysis of Leachate from Weathering Container No. 3

Analyte	Explosives Analyses and Method Detection Limit '(μg/L) Date									
(μg/L)	11/13/1998		01/08/1999		03/10/1999		05/07/1999		08/25/1999	
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
HMX	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
RDX	ND (0.647)	ND (0.616)	ND (0.632)	ND (0.632)	ND (0.505)	ND (0.537)	ND (0.600)	ND (0.576)	ND (0.600)	ND (0.584)
TRI-RDX	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
MONO-RDX	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
TNT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
TNB	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
2,6-DA-4-NT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
2,4-DA-6-NT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
2,6-DNT	ND (0.647)	ND (0.616)	ND (0.632)	ND (0.632)	ND (0.505)	ND (0.537)	ND (0.600)	ND (0.576)	ND (0.600)	ND (0.584)
2,4-DNT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
2-ADNT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
4-ADNT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.526)	ND (0.421)	ND (0.447)	ND (0.500)	ND (0.480)	ND (0.500)	ND (0.487)
Volume (L)	3		7.89		18.2		22.6		3.5	

ND = Not Detected (Below detection limits)
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
TRI-RDX = Trinitroso-RDX
MONO-RDX = Mononitroso-RDX
TNT = 2,4,6-Trinitrotoluene
TNB = Trinitrobenzene
2,6-DA-4-NT = 2,6-Diamino-4-nitrotoluene
2,4-DA-6-NT = 2,4-Diamino-6-nitrotoluene
2,6-DNT = 2,6-Dinitrotoluene
2,4-DNT = 2,4-Dinitrotoluene
2-ADNT = 2-Amino-4,6-dinitrotoluene
4-ADNT = 4-Amino-2,6-dinitrotoluene

Table 6. Analysis of Leachate from Weathering Container No. 4

Analyte (µg/L)	Explosives Analyses and Method Detection Limit '(µg/L) Date									
	11/13/1998		01/08/1999		03/10/1999		05/07/1999		08/25/1999	
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
HMX	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
RDX	ND (0.647)	ND (0.616)	ND (0.632)	ND (0.616)	ND (0.537)	ND (0.568)	ND (0.553)	ND (0.545)	ND (0.537)	ND (0.553)
TRI-RDX	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
MONO-RDX	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
TNT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
TNB	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
2,6-DA-4-NT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
2,4-DA-6-NT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
2,6-DNT	ND (0.647)	ND (0.616)	ND (0.632)	ND (0.616)	ND (0.537)	ND (0.568)	ND (0.553)	ND (0.545)	ND (0.537)	ND (0.553)
2,4-DNT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
2-ADNT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
4-ADNT	ND (0.539)	ND (0.513)	ND (0.526)	ND (0.513)	ND (0.447)	ND (0.474)	ND (0.461)	ND (0.454)	ND (0.447)	ND (0.461)
Volume (L)	6.62		5.17		20.5		19		7.5	

ND = Not Detected (Below detection limits)
HMX = Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
TRI-RDX = Trinitroso-RDX
MONO-RDX = Mononitroso-RDX
TNT = 2,4,6-Trinitrotoluene
TNB = Trinitrobenzene
2,6-DA-4-NT = 2,6-Diamino-4-nitrotoluene
2,4-DA-6-NT = 2,4-Diamino-6-nitrotoluene
2,6-DNT = 2,6-Dinitrotoluene
2,4-DNT = 2,4-Dinitrotoluene
2-ADNT = 2-Amino-4,6-dinitrotoluene
4-ADNT = 4-Amino-2,6-dinitrotoluene

The results of chemical analyses of the compost are shown in Tables 7, 8, and 9. For each sample, the analytical method detection limits for each analyte are given in parentheses. Compost samples taken from each container were combined so that the top, middle, and bottom layers of compost in each weathering container could be separately analyzed (compost sampling is discussed in the Experimental Design section).

The only analyte detected was trinitrobenzene. TNB was detected in all three layers (top 15 cm, middle 15 cm, and bottom 15 cm) in weathering container No. 1. In container No. 2 it was detected in the top and middle layers and in container No. 3 it was detected in only the top layer. The middle layer from the first weathering container had the highest concentration of TNB, 0.43 mg/Kg. The other quantifiable concentrations ranged from 0.15 to 0.37 mg/Kg. TNB is both an impurity from the manufacture of TNT and a breakdown product. TNB's presence in the compost and absence in the leachate reflects its strong tendency to be adsorbed on organic matter. TNB also appears to be more recalcitrant to aerobic biodegradation than TNT. The concentration of TNB in the immature compost delivered to TVA in July of 1996 was 245 μg/Kg. This was about four times the concentration of TNT in the immature compost (64 μg/Kg). After the first year of weathering, TNB was the only analyte detected in the compost. Samples taken after the second year of weathering yielded no detections for TNB. The second-year samples were taken from the full depth of the compost.

Table 7. Results of Analyses of Compost from the No. 1 Weathering Container

Analyte	Analyte Concentration and Method Detection Limit (mg/Kg)		
	Top 15 cm	**Middle 15 cm**	**Bottom 15 cm**
HMX	ND (0.15)	ND (0.15)	ND (0.14)
RDX	ND (0.1)	ND (0.098)	ND (0.094)
TRI-RDX	ND (0.1)	ND (0.098)	ND (0.094)
MONO-RDX	ND (0.1)	ND (0.098)	ND (0.094)
TNT	ND (0.1)	ND (0.098)	ND (0.084)
TNB	**0.15** (0.1)	**0.43** (0.098)	**0.19** (0.084)
2,6-DA-4-NT	ND (1.5)	ND (1.5)	ND (1.3)
2,4-DA-6-NT	ND (1.0)	ND (0.98)	ND (0.84)
2,6-DNT	ND (0.1)	ND (0.098)	ND (0.084)
2,4-DNT	ND (0.1)	ND (0.098)	ND (0.084)
2-ADNT	ND (0.1)	ND (0.098)	ND (0.084)
4-ADNT	ND (0.1)	ND (0.098)	ND (0.084)

ND = Not detected (below detection limits)

Table 8. Results of Analyses of Compost from the No. 2 Weathering Container

Analyte	Analyte Concentration and Method Detection Limit (mg/Kg)		
	Top 15 cm	**Middle 15 cm**	**Bottom 15 cm**
HMX	ND (0.14)	ND (0.14)	ND (0.15)
RDX	ND (0.094)	ND (0.096)	ND (0.1)
TRI-RDX	ND (0.094)	ND (0.096)	ND (0.1)
MONO-RDX	ND (0.094)	ND (0.096)	ND (0.1)
TNT	ND (0.094)	ND (0.096)	ND (0.1)
TNB	**0.37** (0.094)	**0.21** (0.096)	ND (0.1)
2,6-DA-4-NT	ND (1.4)	ND (1.4)	ND (1.5)
2,4-DA-6-NT	ND (0.94)	ND (0.96)	ND (1.0)
2,6-DNT	ND (0.094)	ND (0.096)	ND (0.1)
2,4-DNT	ND (0.094)	ND (0.096)	ND (0.1)
2-ADNT	ND (0.094)	ND (0.096)	ND (0.1)
4-ADNT	ND (0.094)	ND (0.096)	ND (0.1)

ND = Not detected (below detection limits)

Table 9. Results of Analyses of Compost from the No. 3 Weathering Container

Analyte	Analyte Concentration and Method Detection Limit (mg/Kg)		
	Top 15 cm	**Middle 15 cm**	**Bottom 15 cm**
HMX	ND (0.14)	ND (0.15)	ND (0.15)
RDX	ND (0.096)	ND (0.1)	ND (0.1)
TRI-RDX	ND (0.096)	ND (0.1)	ND (0.1)
MONO-RDX	ND (0.096)	ND (0.1)	ND (0.1)
TNT	ND (0.096)	ND (0.1)	ND (0.1)
TNB	**0.31** (0.096)	ND (0.1)	ND (0.1)
2,6-DA-4-NT	ND (1.4)	ND (1.5)	ND (1.5)
2,4-DA-6-NT	ND (0.96)	ND (1.0)	ND (1.0)
2,6-DNT	ND (0.096)	ND (0.1)	ND (0.1)
2,4-DNT	ND (0.096)	ND (0.1)	ND (0.1)
2-ADNT	ND (0.096)	ND (0.1)	ND (0.1)
4-ADNT	ND (0.096)	ND (0.1)	ND (0.1)

ND = Not detected (below detection limits)

Conclusions

The following conclusions can be drawn from the third year of this microbial weathering study.

- As in the first two years of the microbial weathering study, leachate from the compost contained no TNT or TNT degradation products indicating that these compounds were effectively degraded in the composting operation.
- Extremely low levels of RDX were found in leachate from one of the compost containers early in the third year of the study indicating that the compost operation did not completely degrade RDX.
- The RDX contained in the leachate appeared to be in solution and not attached to solids or bacteria.
- After being weathered three years, some compost samples contained low levels of TNB, <0.5 mg/Kg.
- TNB's presence in compost and absence in leachate reflects its strong tendency to be adsorbed on organic matter.

References

1. USAEC Report No. SFIM-AEC-ET-CR-98042. *Results of a Microbial Weathering Study of Composted Explosives-Contaminated Soil Obtained from the Umatilla Army Depot Activity.* October 1998

2. USAEC Report No. SFIM-AEC-ET-CR-98043. *Results of a Study Investigating the Plant Uptake of Explosive residues From Compost of Explosives-Contaminated Soil Obtained from the Umatilla Army Depot Activity.* November 1998.